

VACUUM-PRESSURE SOAK PLUS OVENDRY AS AN ACCELERATED-AGING TEST FOR WOOD-BASED PANEL PRODUCTS

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ABSTRACT

Vacuum-pressure soak (VPS) at room temperature was investigated as an alternative to the hot water soak and steaming steps in the current ASTM D 1037 accelerated-aging tests. Oriented strandboard, flakeboard, isocyanate-bonded particleboard, and hardboard siding were included. The effects of steaming and cyclic hot water soak plus ovdry (OD) exposure were also investigated. For the phenolic-bonded flakeboard, the various alternative exposures had essentially the same effect on static bending and in-plane shear properties as the standard test. For the other materials, the exposures that were closest to the standard for these materials were four cycles of VPS plus steam plus OD and four cycles of hot water soak (93°C) plus OD. The 93°C temperature was greater than that used in the soaking step of the standard test (49°C). Four cycles of VPS at room temperature plus OD and six cycles of steam (93°C) plus OD were the least severe exposures. The hot water soak plus OD was the most likely candidate as an alternative to the six-cycle test because it was the simplest and least time consuming.

The six-cycle accelerated-aging test in ASTM D 1037 (2) is considered too time consuming for use as an in-plant quality control procedure (1). Earlier research has indicated that several opportunities exist to shorten the exposure without significantly affecting test results:

1. The first exposure to extreme moisture conditions releases most of the compression stresses built into wood-based panels during manufacture (4,5,11,13).
2. Freezing has little or no effect on board properties (3,9,13).
3. A small increase in water (or steam) temperature results in a large decrease in mechanical properties (7,8,12).
4. A cyclic vacuum-pressure soak plus ovdry (VPS-OD) exposure for flakeboards correlated well with the ASTM six-cycle test (6).

This is the third in a series of studies on the analysis of, and alternatives to, the current six-cycle accelerated-aging test

in ASTM D 1037. The first study (9) evaluated the effects of the number of cycles and the specific steps in the cycle on properties of oriented strandboard (OSB), waferboard, phenolic-bonded flakeboard, isocyanate-bonded particleboard, and hardboard siding. Four cycles of exposure, with the freezing step deleted, had essentially the same effect on static bending properties as the ASTM D 1037 exposure. In the second study (10), two simplified cyclic hot water soak (49°C) plus OD (99°C) exposures were compared to the standard test using OSB,

phenolic-bonded flakeboard, isocyanate-bonded particleboard, and hardboard siding. Bending properties after the standard and the two simplified exposures were about the same for the particle panel products. However, hardboard properties were less affected by the hot water soak plus OD exposures because less water was adsorbed without the steaming step.

The objective of this study was to evaluate VPS-OD as a simpler, less time-consuming accelerated-aging test than the current ASTM D 1037 six-cycle test. It was hoped that VPS could replace the hot water soak (49°C) and steaming (99°C) steps as a means to saturate the wood-based panels. Effects of steaming and increasing water-soak temperature from 49°C to 93°C were also investigated.

EXPERIMENTAL PROCEDURE

The study consisted of five cyclic accelerated-aging exposures of five wood-based products followed by a determination of selected properties. Not all products were subjected to all five exposures. The five accelerated-aging exposure methods are detailed in **Table 1**.

In the VPS exposures, the specimens were submerged in water in a pressure vessel, the -88-kPa vacuum was pulled

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Table 1. — Detailed exposure steps included in each cycle of the five accelerated-aging tests used in this study.

Exposure method	Temperature (°C)	Pressure (kPa)	Time (hr.)
ASTM D 1037 ^a			
Hot water soak	49		1
Steam	93		3
Freeze	-12		20
Ovendry	99		3
Steam	93		3
Ovendry	99		18
VPS-OD ^b			
Vacuum		-88	0.5
Pressure soak		345	1
Ovendry	99		22
VPS-S-OD ^c			
Vacuum		-88	0.5
Pressure soak		345	1
Steam	93		1
Ovendry	99		21
HW-OD ^d			
Hot water soak	93		3
Ovendry	99		21
S-OD ^e			
Steam	93		3
Ovendry	99		21

^a ASTM D 1037 standard test; consisted of six cycles for a total exposure time of 288 hours.

^b Vacuum-pressure soak plus ovendry; consisted of four cycles for a total exposure time of 94 hours; steps 1 and 2 done in cold tap water.

^c Vacuum pressure soak plus steam plus ovendry; consisted of four cycles for a total exposure time of 94 hours; steps 1 and 2 done in cold tap water.

^d Hot water soak plus ovendry; consisted of four cycles for a total exposure time of 96 hours.

Table 2. — Initial properties of five wood-based panels.^a

Panel product	Moisture content (%)	Specific gravity ^b	MOE	MOR	In-plane shear strength
			(MPa)		
Oriented strandboard	8.6 (0.2)	0.56 (0.02)	4260 ^c (507)	22.7 ^c (5.0)	2.5 (0.4)
Flakeboard	10.0 (0.2)	0.64 (0.01)	4780 (274)	33.3 (3.2)	3.5 (0.8)
Particleboard	9.2 (0.2)	0.70 (0.02)	3570 (226)	20.9 (1.6)	6.1 (0.6)
Hardboard A	7.0 (0.3)	0.87 (.03)	3460 (327)	20.8 (2.7)	6.6 (1.2)
Hardboard B	6.4 (0.04)	0.87 (0.01)	4030 (112)	28.7 (1.6)	4.9 (0.5)

^a All values are least square means. Standard deviations are shown in parentheses. Tested at equilibrium at 24°C and 64 percent RH.

^b Based on ovendry weight and dimensions at test.

^c Parallel to face strand alignment.

for 30 minutes, then the 345-kPa pressure was applied for 1 hour.

Initial properties of the five panel products included in this study are shown in **Table 2**. The three-layer phenolic-bonded flakeboard was made at the USDA Forest Service, Forest Products Laboratory (FPL). The others were commercial panels. All were nominally 13 mm thick except for the two primed hardboard siding products (A and B), which were 10 mm thick. Three of the panel products from the previous two

studies were included: flakeboard, isocyanate-bonded particleboard, and hardboard A. The laboratory-made flakeboard was included because it was similar to the material evaluated by Lehmann (6).

The hardboards were cut into 76-mm by 279-mm static bending specimens. The other panels were cut into 76-mm by 356-mm specimens to maintain the same span-depth ratio for all bending specimens. The OSB specimens were cut so that the face strands were aligned lengthwise. All specimens were conditioned to

equilibrium moisture content (EMC) at 24°C and 64 percent relative humidity (RH) prior to exposure. For the controls and two of the exposures (ASTM and VPS-OD), 20 specimens from each type of board except hardboard B were randomly chosen. For the vacuum pressure soak plus steam plus ovendry (VPS-S-OD), hot water plus ovendry (HW-OD), and steam plus ovendry (S-OD) exposures, six specimens were randomly selected from each type of board. Hardboard A was not used in the S-OD exposure due to lack of specimens. Because of a limited number of specimens, we used six Hardboard B and 10 control and ASTM-exposure specimens in the S-OD exposure.

After the specimens were subjected to accelerated-aging, they were reconditioned, remeasured, and tested in static bending according to ASTM D 1037. As specified in ASTM D 1037, modulus of elasticity (MOE) and modulus of rupture (MOR) were calculated based on both the original dimensions and dimensions after accelerated aging. When these properties were based on original dimensions, they were referred to as bending resistance (BR) and load-carrying capacity (LCC), respectively. A specimen for determining in-plane shear strength using the compression shear test in ASTM D 1037 was then cut from the end of each specimen.

We obtained linear relationships for the various individual property values between the ASTM test and the four alternate exposures using the model:

$$y = a + bx + \varepsilon \quad [1]$$

where:

y = ASTM test value of a property

x = corresponding alternate test value

a and b = parameters that we are estimating

ε = random error with standard deviation σ

RESULTS AND DISCUSSION

Figure 1 shows MOR of the test materials after the four alternative exposures as compared to the ASTM six-cycle test. Relationships were similar for MOR as well as for LCC and bending resistance. **Figure 2** shows the same information for in-plane shear strength. In **Figure 3**, average MOR of the materials after the standard ASTM D 1037 accelerated-aging exposure is compared to average

MOR after the four alternative exposures. Properties of the flakeboard after the four alternative exposures were essentially the same as properties after the ASTM test. This agrees with results of the study by Lehmann (6). For the OSB and particleboard, on the other hand, almost all the alternatives were significantly less severe than the ASTM test (Fig. 3). Both the HW-OD exposure and the VPS-S-OD exposure gave results similar to the ASTM test.

Using the model from Equation [1], r^2 was higher for the relationship between ASTM and VPS-S-OD. It ranged from 0.85 for load-carrying capacity to 0.94 for shear strength. The plot for MOR is shown in Figure 4. The equation for the line through the data is $y = -16.8 + 0.91x$. Corresponding r^2 for the relationship between ASTM and HW-OD ranged from 0.71 for load-carrying capacity to 0.87 for shear strength.

Results from the second study in this series (10) suggested that perhaps VPS-OD could be substituted for the ASTM exposure. VPS effectively forced water into the panels. Water adsorption from VPS ranged from about 60 percent for the hardboard to 130 percent for the OSB. In this study, however, it had less effect on board properties than did the ASTM test. Exposure to steam alone resulted in water adsorption values of no more than 20 percent for any of the panels. Thus, the S-OD cycle was the least severe of the five exposures, as indicated by the lowest residual thickness swelling (Fig. 5) and least reduction in properties.

CONCLUSIONS

The ASTM D 1037 accelerated-aging test and four alternative exposures were evaluated using OSB, laboratory-made flakeboard, isocyanate-bonded particleboard, and two hardboard siding products. The alternatives were cyclic exposures with one step (in one case, two steps) to saturate the specimens with moisture plus an overdrying step. The saturation methods included vacuum-pressure soaking, steaming, and hot-water soaking. Bending strength and stiffness, in-plane shear strength, and residual thickness swelling were determined. In most cases, the effects of the alternative exposures on board properties were not as severe as the ASTM test. Vacuum-pressure soaking in cold tap water completely saturated the specimens in the shortest time (1.5 hr.) but

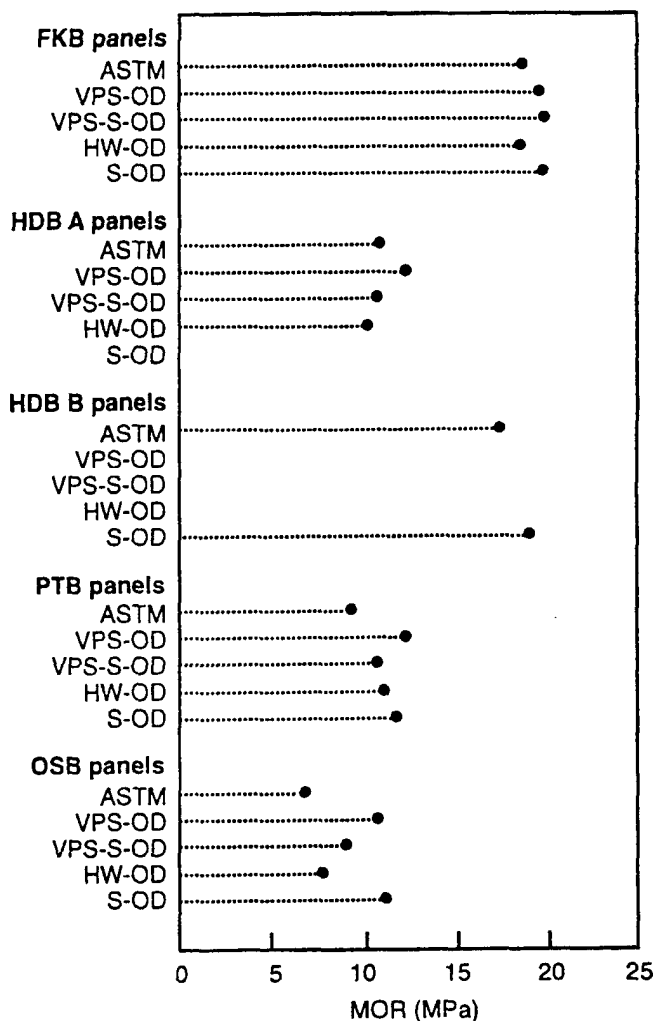


Figure 1. — The MOR of five panel products after various accelerated-aging exposures. FKB = flakeboard; OSB = oriented strandboard; HDB = hardboard; PTB = particleboard.

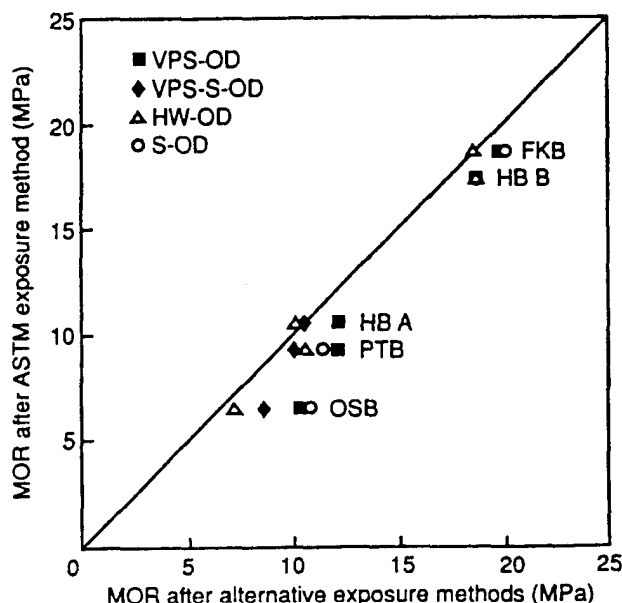


Figure 3. — Comparison of MOR of the materials after the standard ASTM D 1037 accelerated-aging exposures and after four alternative exposures.

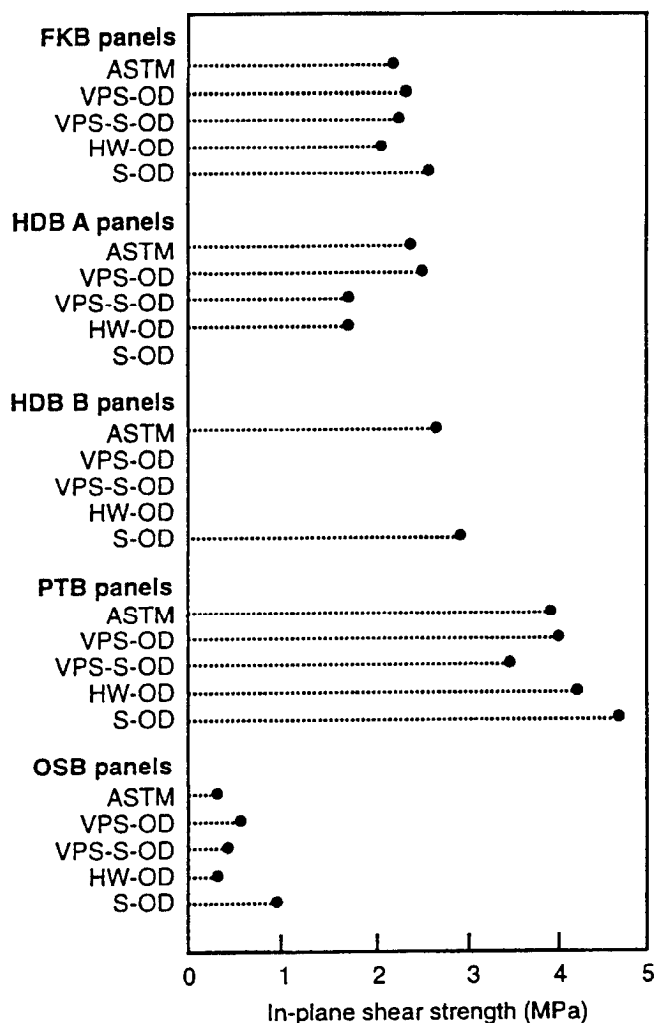


Figure 2. — Compression-shear properties after various accelerated-aging exposures.

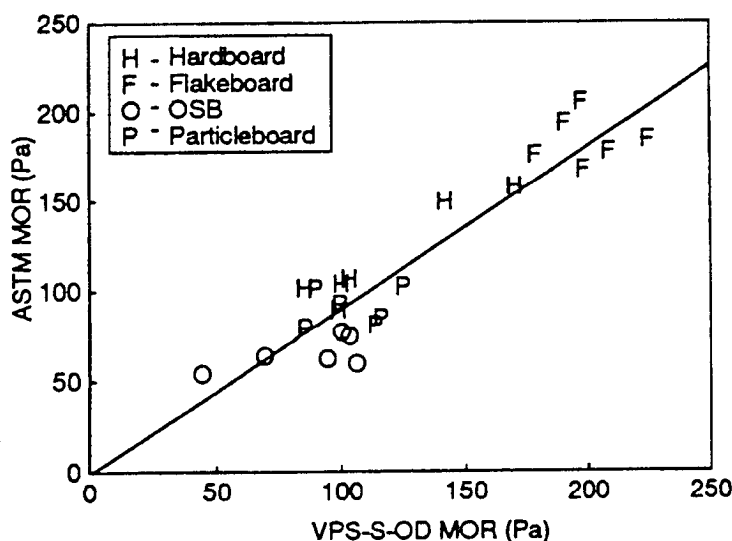


Figure 4. — Linear relationships between MOR after the standard ASTM D 1037 exposure and after the VPS-S-OD exposure.

reduction in board properties from the VPS-OD exposure did not equal either that of the same exposure with a steaming step added or the ASTM exposure. Steaming alone was the least effective way to add moisture. Of the four alternatives, HW-OD produced results most like the ASTM test. The cold water, VPS-OD method was slightly less effective. Perhaps VPS with hot rather than cold water would be more appropriate. As others have reported, it appears that no single test will produce results equivalent to the ASTM standard for all board types.

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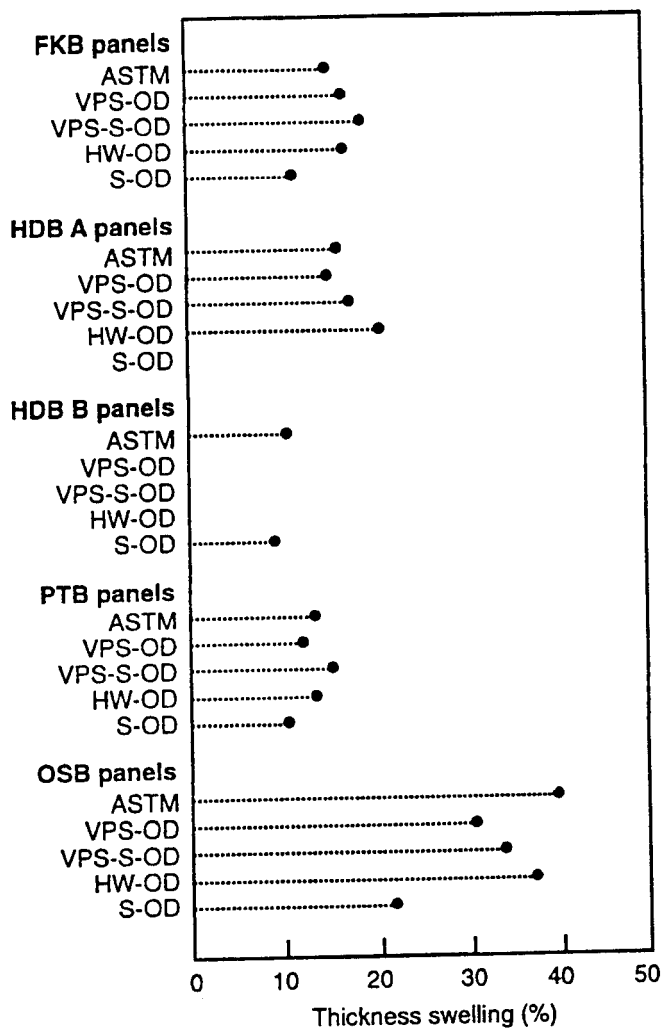


Figure 5. — Residual thickness swelling of the panel products after various aging exposures.

